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FINE STRUCTURE OF THE MEISSNER CORPUSCLE OF HUMAN PALMAR SKIN*

KEN HASHIMOTO, M.D.

ABSTRACT

Meissner corpuscles of human palmar skin were investigated with the electron microscope. The upper margin of the corpuscle was in direct contact with the epidermal basal cells without interposition of the basal lamina. Although no specialized junctions were formed, axon terminals and accompanying laminar cells were interdigitated with the basal cells. Axons, both those in contact with the epidermis and those terminated within the corpuscle, contained a number of mitochondria, microvesicles similar to synaptic vesicles, and myelinated dense bodies. Some axon terminals contained dense granules identical to those of the Merkel cell or chromaffin cells. Axon cylinders were enveloped with single or multiple layers of laminar cells and their processes which produced desmosome-like junctions between them. Laminar cell nuclei tended to localize at the periphery of the corpuscle and their cytoplasm extended unipolarly. Slender cytoplasmic processes often produced desmosome-like junctions between themselves, contained numerous pinocytotic vesicles, and were surrounded with a basal lamina in many areas. The laminar cell was considered to be a modified Schwann cell. Spaces between laminar cells and their processes were filled with an *interlaminar substance* which was composed of an admixture of basal lamina materials, microfilaments, and collagen fibrils.

Meissner's tactile corpuscle of hairless skin has been studied histologically and histochemically by a number of investigators [1, 2]. Electron microscopic studies were done by Cauna and Ross [3], Breathnach [4], and others [5–7]. These studies showed that the receptor organ is composed of two types of cells, the axon and laminar cells [3–7]. The axon contains numerous mitochondria and terminates with a swelling. The laminar cells are closely attached to the axon and envelop it [3–7]. The entire corpuscle is enveloped with both basement membrane and fine fibrillar material which enter into the corpuscle and fill the spaces between the laminar cells [3–7].

No description is found in the literature concerning the relationship of this receptor to the epidermis. The nature of the laminar cell is still controversial [4–6] and the fine structure of axon terminals within the corpuscle has not been described in detail. In the present communication, the following will be reported: (i) a direct contact of axon terminal and laminar cells with the epidermal basal cells, (ii) intra-epidermal axon terminals, (iii) the details of enclosure of the axon by the laminar cell, (iv) the presence of dense-cored granules similar to those of the Merkel cell and to noradrenalin granules of the chromaffin cell, and (v) several hitherto undescribed fine structural features of the Meissner corpuscle.

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* From the Memphis Veterans Administration Hospital and Division of Dermatology, Department of Medicine, The University of Tennessee College of Medicine, Memphis, Tennessee 38104.

MATERIALS AND METHODS

Palmar skins were biopsied under 1% procaine local anesthesia from two normal adult volunteers: Two specimens taken from the first individual contained two Meissner corpuscles and one specimen from the second volunteer had one corpuscle (Fig. 1). Routine methods of our laboratory were used for the fixation, dehydration, embedding, thin sectioning, and staining [8]. In most cases serial sections were made to follow the contact areas of the receptor with the epidermis. Thin sections were observed in an Hitachi HU-11C or Hitachi HU-12 electron microscope at an accelerating voltage of 100 KV or 125 KV, respectively. Merkel cells from human oral gingiva were used for the purpose of comparison [8].

RESULTS

Contact with the epidermis. The upper end of the Meissner corpuscle in the dermal papilla showed a few areas of direct contact with the epidermal basal cell (Fig. 2). In such areas, the basal lamina of the epidermis was absent and either axon or laminar cells were in contact with the basal plasma membrane of the basal cell (Fig. 3). In some instances, the axon or laminar cell was invaginated into or interdigitated with the basal cell (Figs. 4A, B). Some axon terminals were found in the basal layer of the epidermis (Fig. 4B). In spite of these interdigitations, there were no specialized contact devices of the cytomembrane, either on the axon or on the epidermal basal cell. No junctional complex was present. Neither the axon terminals nor apposed basal cells contained microvesicles similar to synaptic vesicles or granules similar to those of the Merkel cell or chromaffin cells. Dense-cored granules were, however,

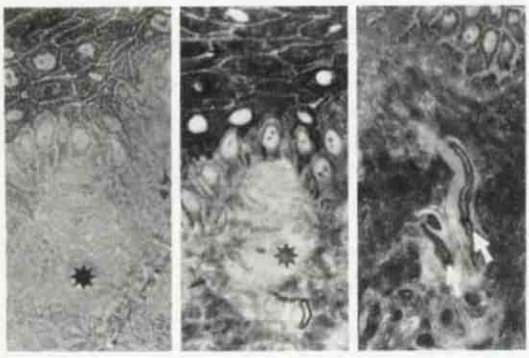

FIG. 1. Meissner corpuscles (*) are shown in 1-μ-thick sections cut from the same tissue blocks that were used for electron microscopic examination. In the right picture, a bundle of axon cylinders (arrows) can be seen as a dense fiber coursing through the center of the corpuscle. × 250.

found in the terminals not associated with the epidermis (see below and Fig. 8A).

Axon. Axons at the epidermal junction and within the corpuscle terminated with a swelling of various shapes and sizes, most commonly forming oblong bulbs (Figs. 2–4A). They were surrounded with slender processes of laminar cells (Figs. 3, 4A). A large number of mitochondria, numerous small vesicles of an average diameter of 300–400 Å (Figs. 3, 4A) and a varying number of myelin-like, concentrically laminated dense bodies, some of which might represent degenerated mitochondria, were seen in the axon terminals (Figs. 2–4B). The non-terminal portion of the axon, the axon cylinder, contained less numerous mitochondria and small vesicles. Varying numbers of micro- or neurotubules were seen (Figs. 5, 6). These axon cylinders were singly, doubly, or triply enveloped with the cytoplasm or processes of a laminar cell or

FIG. 2. Meissner corpuscle is engaged in the upper end of a dermal papilla. In two places either laminar cell (1) or axon terminal (2) is in direct contact with the epidermal basal cell. The basal lamina is discontinued (solid small arrows) in such contact areas. a: axon terminals within the corpuscle. B: basal cells of the epidermis. N: peripherally located nucleus of a laminar cell. Hollow arrow: bending of a unipolar cytoplasmic process of the labeled laminar cell. × 6,150.

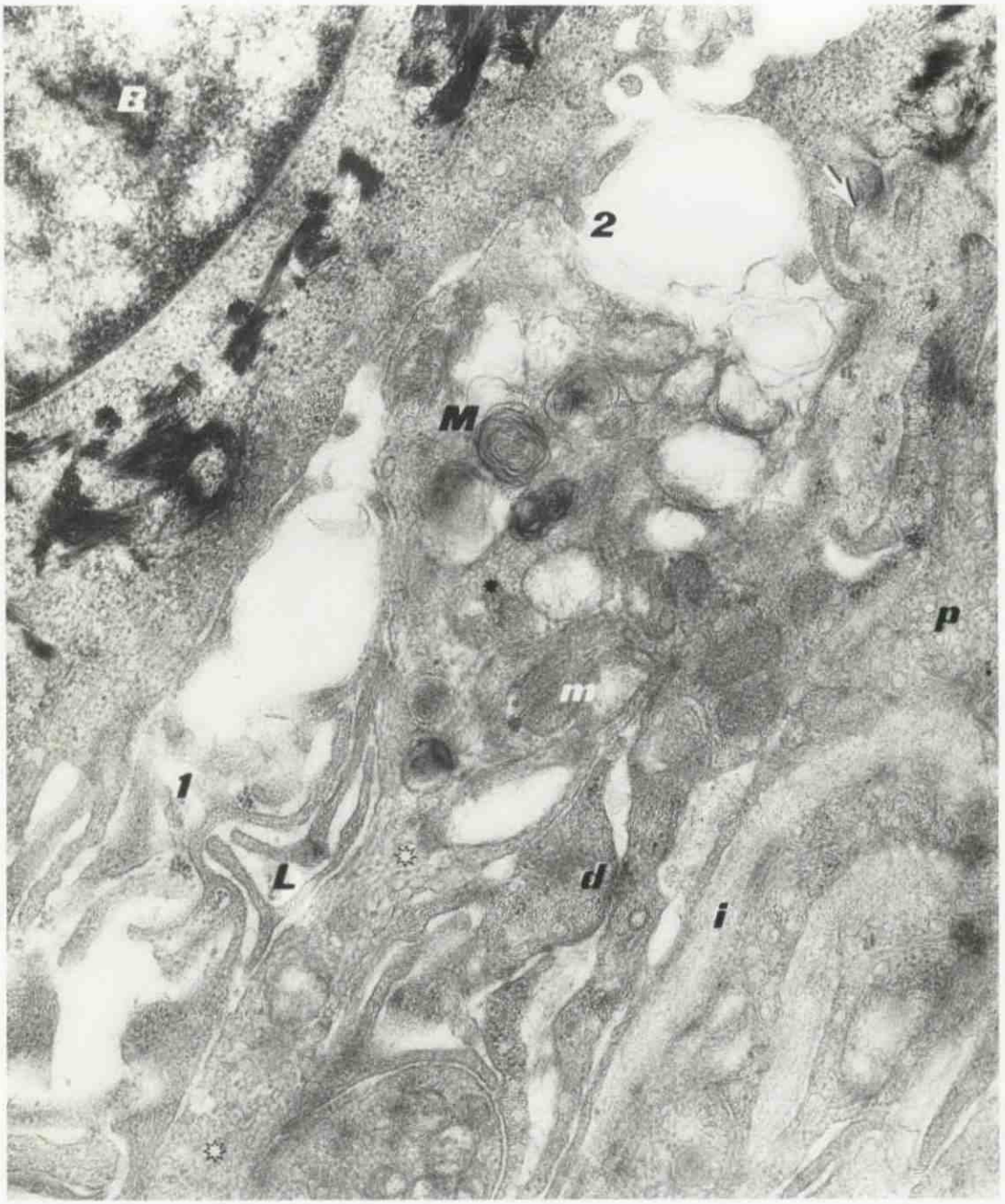

FIG. 3. High magnification of the left upper part of Fig. 1. Bulb-shaped axon terminal contains mitochondria (m), myelin bodies (M), and microvesicles (black *). Axon cylinder contains microvesicles (white *) but no mitochondria. The terminal and cylinder are surrounded with processes of the laminar cell (L) which interdigitate with those of the epidermal basal cell (B) at 1. The terminal bulb touches the basal cell at 2. Arrow: discontinuation of basal lamina. d: desmosome-like junction between two laminar cell processes. i: interlaminar substance. p: pinocytotic vesicles of laminar cell. × 29,250.

cells (Figs. 5–7A), as the Schwann cell envelops unmyelinated axons. Some cylinders were partially enveloped with laminar cells and partially with the basal lamina (Fig. 5). Processes of the laminar cell which enveloped the axon produced desmosome-like junctions between themselves (Figs. 6A, B). Schwann cells and their processes, however, formed the same desmosome-like junctions without enclosing the axon (Figs. 7A, B). In one instance axons enclosed in the same Schwann cell were in contact and formed desmosome-like junctions (Fig. 6B). Some axon terminals contained membrane-surrounded dense granules of average sizes of 800–1500 Å (Fig. 8A). Prominent

neurotubules were seen between these granules (Fig. 8A). These terminals were found only occasionally and were mostly located near the periphery of the corpuscle. Compared with the dense granules of the Merkel cell, their sizes, density and membrane-surrounded features were identical.

Laminar cell. Laminar cells contained oval to

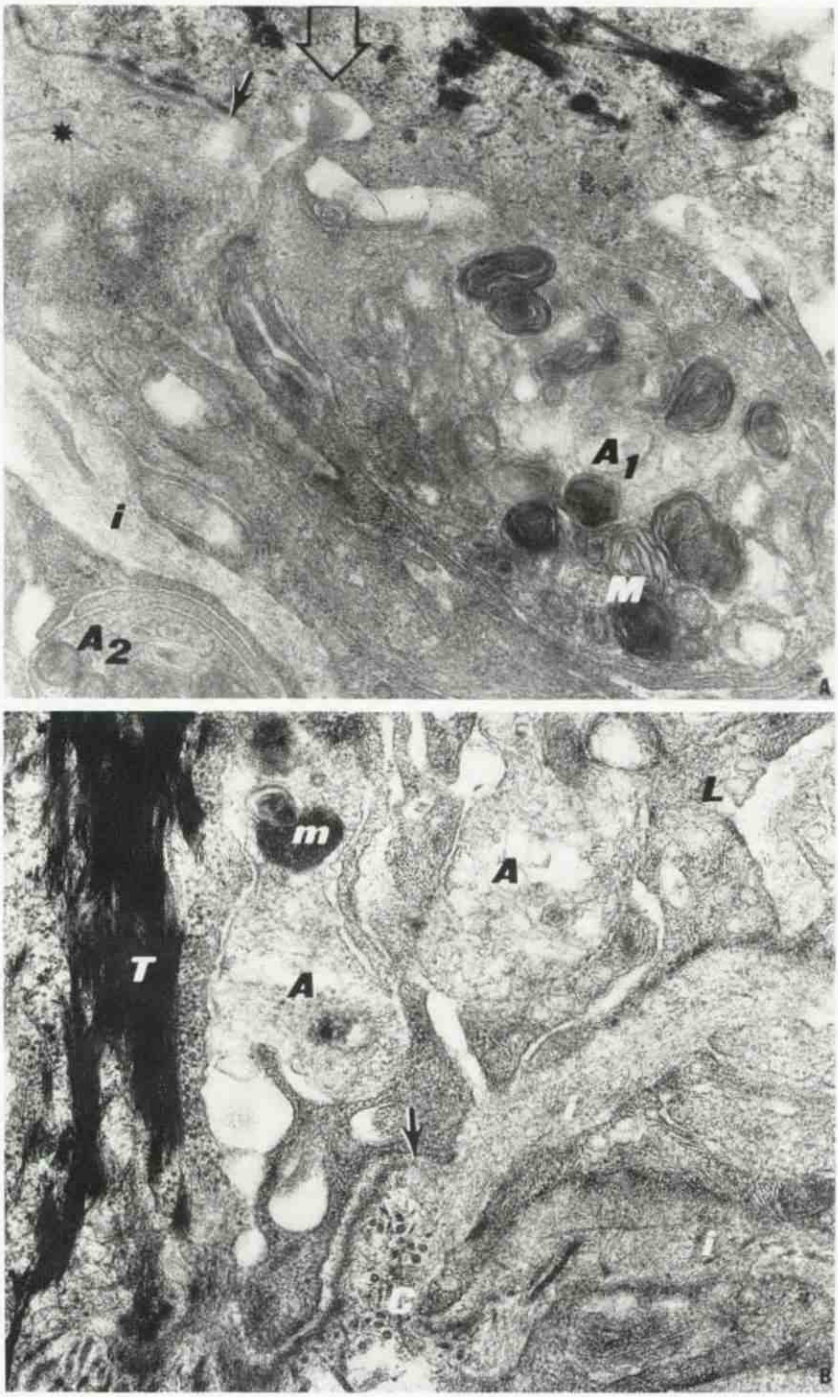

FIG. 4. A. (Top) There are two mitochondria-rich axon terminals (A_1, A_2). A_1 is invaginated into the basal cell of the epidermis (hollow arrow). Basal lamina is disrupted at a solid arrow. i: interlaminar substance. M: myelin body. *: microtubules. × 22,960.

B. (Bottom) The basal lamina of the epidermis is discontinued at the arrow and a part of the corpuscle is situated within the epidermis. A: axon with microvesicles and dense myelin bodies (m). C: capsular collagen. i: interlaminar substance. L: laminar cell with pinocytotic vesicles. T: bundle of tonofibrils. × 30,750.

FIG. 5. Axon cylinder contains mitochondria (m) and neurotubules (solid arrows) and is partially surrounded with two processes of laminar cells (L) and partially with basal lamina (*). Processes of a laminar cell contain numerous pinocytotic vesicles (p). Transverse striations of 1000–1350 Å intervals are seen on thin fibrils (s). Interlaminar substance contains thin collagen fibrils (c). Hollow arrows: half-desmosome-like densities on the cytomembranes of laminar cell. N: nucleus of a laminar cell. × 41,153. Insert: × 23,948.

elongated nuclei, each with a minor indentation or lobulation (Fig. 2). The main body of the laminar cell, where the nucleus is contained, was located at the periphery of the corpuscle (Fig. 2). Perinuclear cytoplasm of some cells contained lipid globules and dense bodies (Fig. 8B). The number of mitochondria in the perikaryon was much smaller than that of the axon. An elongated cytoplasmic process extended either straight (Fig. 5) or folded (Fig. 2) from one side of the cytoplasm. Such a process could branch several times and was either connected with those of neighboring laminar cells through desmosome-like specializations (Fig. 7B), or most commonly was separated from a similar process by an *interlaminar substance* (Figs. 5, 7A, B). As mentioned above, when these processes embraced an axon or axons, desmosome-like junctions often sealed them (Figs. 6A, B). The nucleated portion of the laminar cells contained a relatively small number of pinocytotic vesicles, whereas the extended thin processes could contain numerous pinocytotic vesicles (Fig. 5). The periphery of the laminar cell was surrounded with basal lamina, and half-desmosome-like peripheral densities were produced along the cytomembrane (Figs. 5, 7A). In many instances, however, the *interlaminar substance* was ultrastructurally identical to the material composing the basal lamina, and the existence of a distinct 600 Å-wide basal lamina therefore could not be ascertained (Fig.

7B). Interestingly, even without distinct basal lamina, half-desmosome-like densities could be observed on the cytomembrane of the laminar cell (Figs. 7A, 8A).

Interlaminar substance. Wherever laminar cells and their processes were not in direct contact, the spaces between them were filled with *interlaminar substance.* Towards the center of the corpuscle, this substance was mainly composed of medium-electron-dense amorphous or finely filamentous material very similar to or morphologically undistinguishable from the material which made the

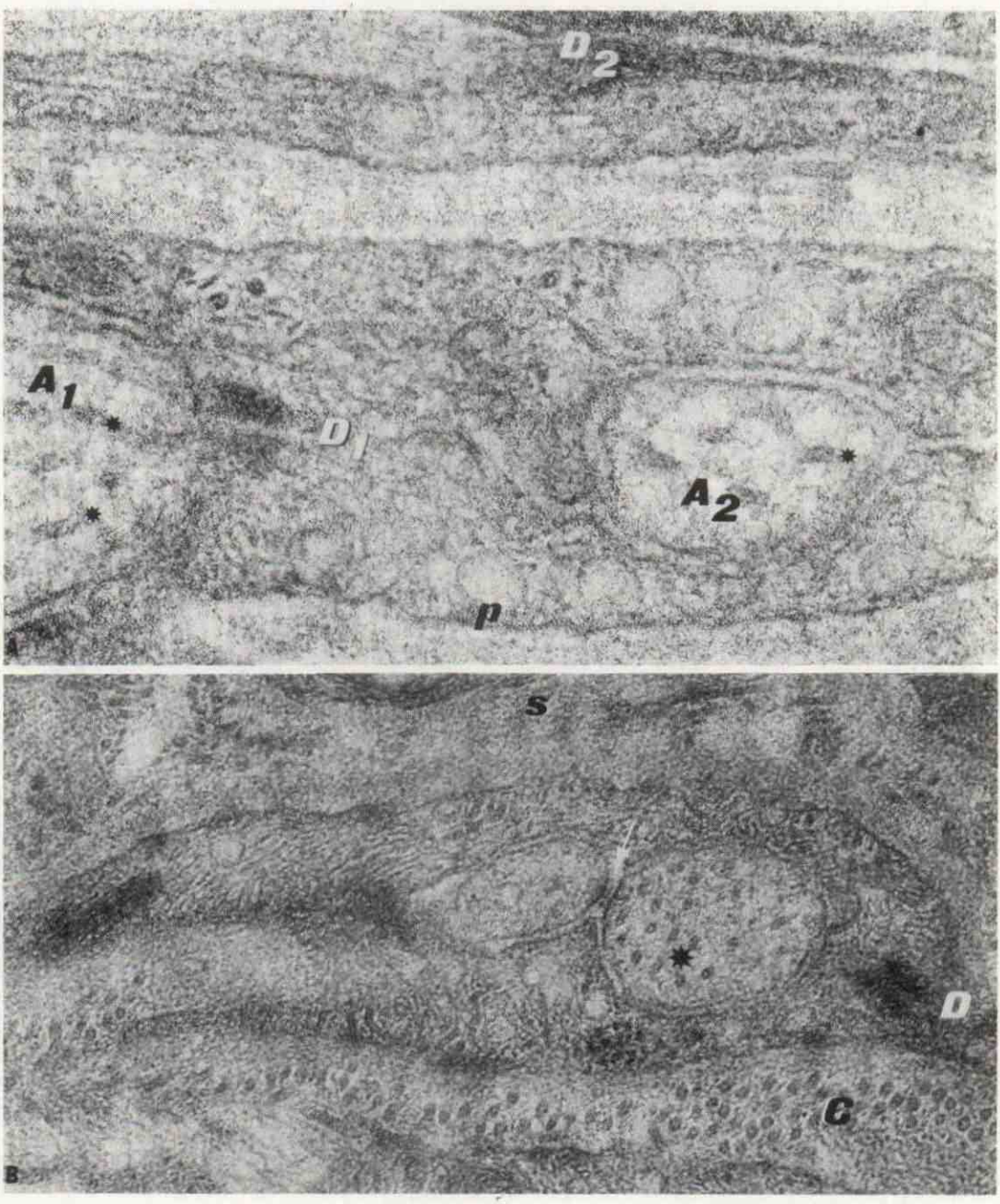

FIG. 6 A. (Top) Axon cylinder is cut in two places (A_1, A_2). Desmosome-like dense areas developed on the cytomembranes of laminar cell processes, one enveloping the axon (D_1) and the other without axon (D_2).*: neurotubules. p: pinocytotic vesicles. × 99,513.

B. (Bottom) Two axon cylinders are enclosed between processes of laminar cell. At the point of contact, these axons developed desmosome-like cytomembrane density and an intercellular dense layer (arrow). *: neurotubules. D: desmosome-like structure sealing the laminar cell processes. C: thin collagen fibrils of interlaminar substance. s: 1000–1350 Å striations on fine filaments (see Fig. 5). × 129,960.

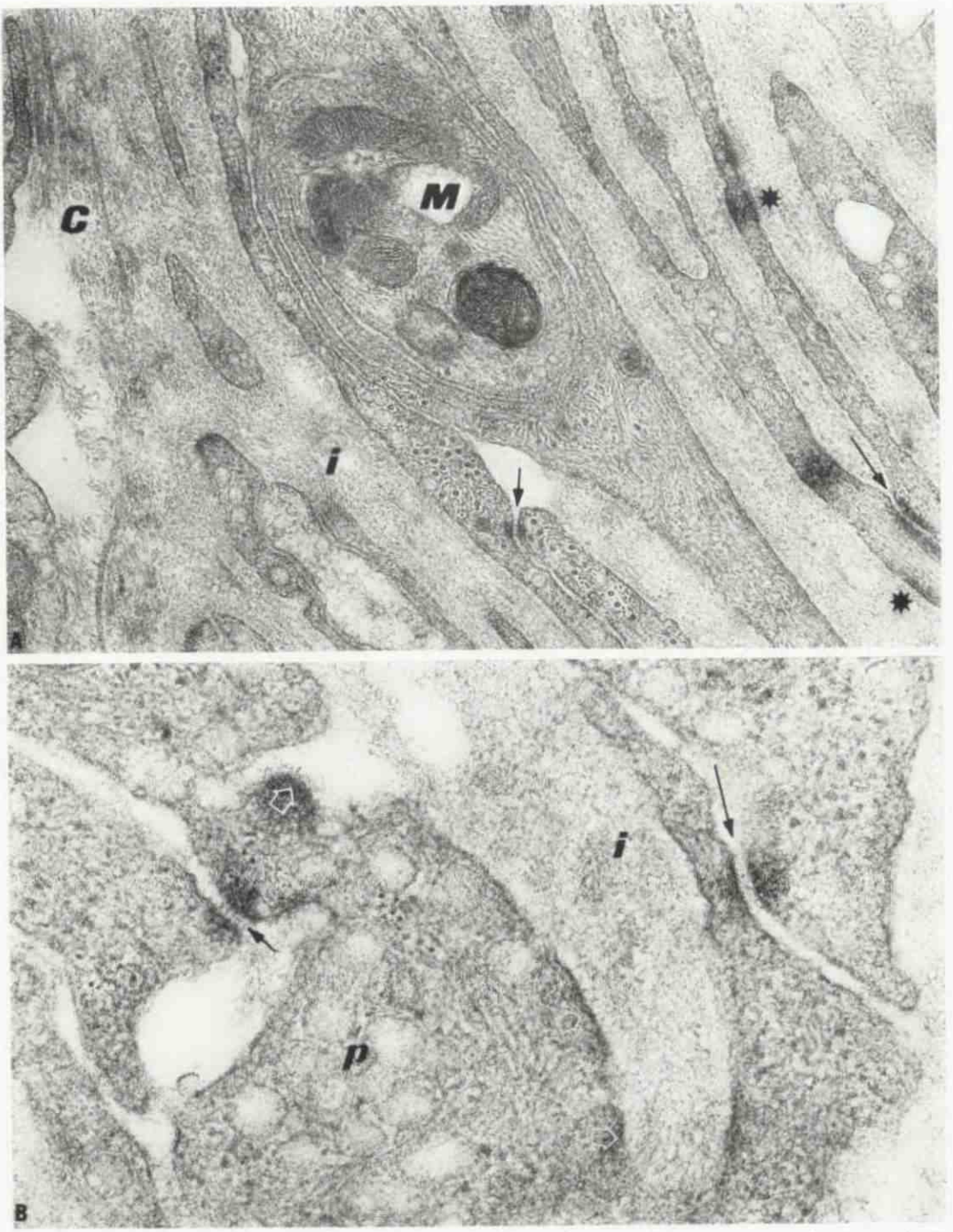

FIG. 7. A (Top) Mitochondria-rich (M) axon is enveloped several times with processes of a laminar cell. Two desmosome-like junctions are formed (arrows) between these processes. Half-desmosome-like densities are also seen (*) with or without apposed basal lamina. Interlaminar substance (i) contains an increasing amount of collagen (C) toward the periphery of the corpuscle. × 30,875.

B. (Bottom) Half-desmosome-like densities (hollow arrows) and desmosome-like junctions (solid arrows) are seen on the cytomembranes of laminar cells. Interlaminar substance (i) is composed mainly of basal lamina-like material. p: pinocytotic vesicles. × 71,250.

basal lamina (Figs. 7A, B). In some specimens, the *interlaminar substance* showed peculiar transverse striations (Figs. 5, 6B) with a periodicity of 1,000–1,350 Å. The striations were found on fine fibrils without periodicity and corresponded to what Breathnach called "coarse periodicity" [4]. We have identified them previously in premature collagen from various conditions such as superfi-

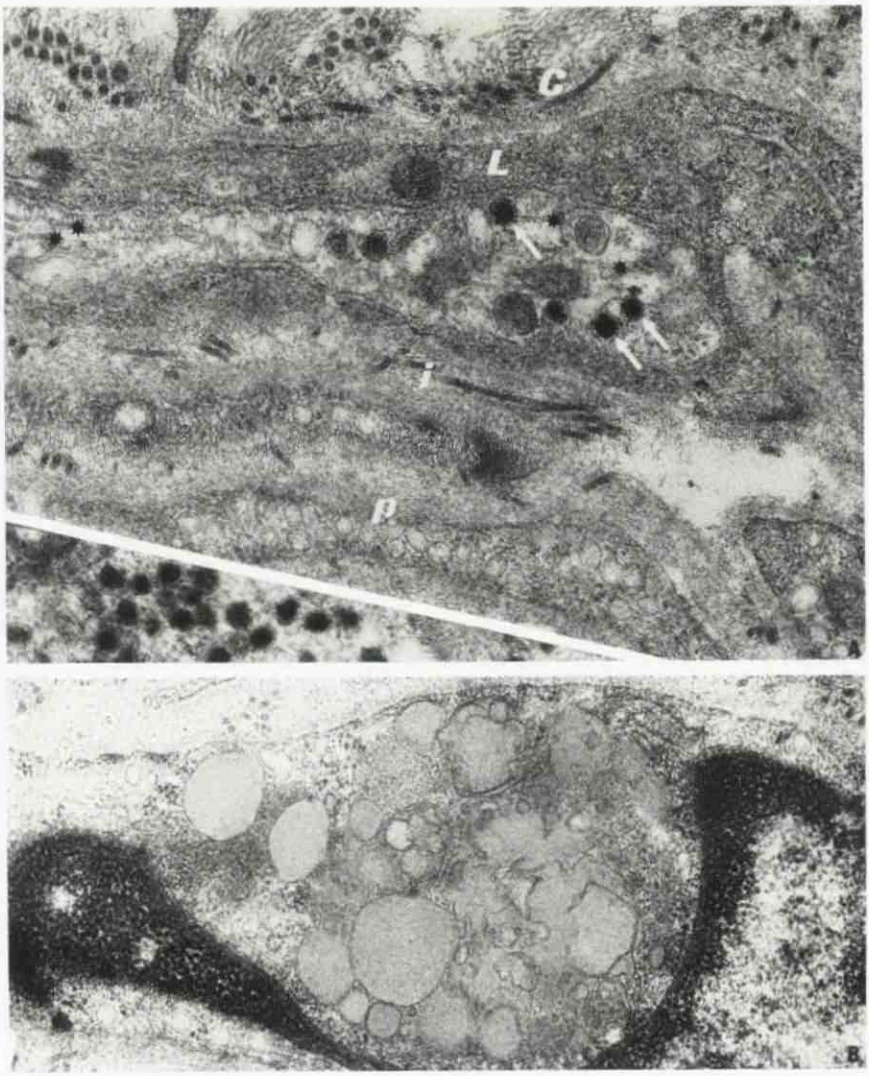

FIG. 8. A. (Top) A bulb-shaped axon terminal at the periphery (C) of the corpuscle contains dense granules of about 800–1500 Å, which are surrounded with membrane (arrows). The terminal also contains neurotubules (*) and is enveloped with a laminar cell (L). Compare these granules with Merkel cell granules at the same magnification (insert). i: interlaminar substance with increased number of collagen fibrils. p: pinocytotic vesicles of laminar cell. × 36,900.
B. (Bottom) Lipid-containing laminar cell is shown. × 30,750.

cial basal cell epithelioma [9]. Toward the periphery of the corpuscle an increasing number of thin collagen fibrils with or without 640 Å periodical banding was seen (Figs. 4B, 6B, 8A). The sizes of collagen admixed also increased toward the periphery. The outer margin of the corpuscle was not delimited by a distinct membrane but by an irregular thickness of the same admixture of these components (Figs. 2, 7A).

DISCUSSION

The present investigation clearly demonstrates that the axon terminals and sheath (laminar cells) are in direct contact with the epidermal basal cells at the upper end of the Meissner corpuscle without interposition of a basal lamina. Free axon terminals were found interdigitating with the processes of the basal cells of the epidermis (Fig. 4B). In human skin, intra-epidermal free nerve endings have never been demonstrated at the fine structural level unless they were associated with Merkel cells [8, 10]. In perifollicular nerve endings*, for example, the axons were usually found separated from the follicular epithelial cells by interposed basal lamina, and no intrafollicular terminals were detected.

In spite of interdigitation and other intimate spatial relations, neither the axon nor the epidermal basal cells in contact developed specialized contact devices. It seems that the epidermis medi-

* Hashimoto K, unpublished observations.

ates mechanical pressure to the corpuscle and an action potential is generated within the deformed terminals which are either interdigitated with the basal cells or sandwiched between lamellar cells. Microvesicles which are morphologically similar to other synaptic vesicles [11] were demonstrated in the axon terminals. They may contain acetylcholine which can be demonstrated in the Meissner corpuscle by histochemical methods [7], but on the other hand, these vesicles could represent pinocytotic vesicles since the sizes of both are similar. Cauna and Ross [3] stated that cholinesterase was contained in laminar cells and not in axons.

Axon terminals containing dense granules have not been reported previously. The presence of prominent neurotubules (Fig. 8A) identifies these cells as axons or neurites and not as dermal Merkel cells. The function of the dense granules is, however, not clear. Although it may be assumed that they subserve the function of adrenergic neurotransmission as do similar granules in chromaffin cells, a chemical analysis of the granules would be necessary before a functional role can be assigned to them. Histochemically, a weak reaction for monoamine oxidase was demonstrated in the Meissner corpuscles of the sole of the adult rat [12].

In the present investigation, single or multiple enveloping of the axon cylinder by laminar cells or their processes was observed. This feature may be analogous to the infolding of the cytomembrane of the Schwann cell (mesaxon formation) which envelops unmyelinated axons. Half-desmosones along the cell periphery and a large number of pinocytotic vesicles are commonly seen in Schwann cells. Although desmosome-like contacts between laminar cells, particularly between the processes sheathing the axon, are not regularly seen in Schwann cells, laminar cells seem to represent modified Schwann cells. They are probably not of perineural [5] or lemmoblastic origin [6], because they directly envelop the axon. This feature was emphasized by Breathnach [4].

The *interlaminar substance* seems to be composed of an admixture of basal lamina material, microfilaments, and collagen fibrils of various sizes. Since there are no fibroblasts in the corpuscle, the *interlaminar substance* may be produced by laminar cells themselves. The function of the substance may be to buffer the pressure and prevent damage to the axon or to insulate the action potentials. It is interesting that such a large receptor organ as the Meissner corpuscle is avascular. It may be postulated that the interlaminar channels filled with various materials serve as a route of fluid diffusion and that the numerous pinocytotic vesicles of laminar cells arranged along the channels take up necessary nutrients. The nature of the amorphous or fine filamentous material seems to be similar to the substance composing the basal lamina. The formation of half-desmosome-like densities on the laminar cell membrane in apposition to the *interlaminar substance* seems to support this hypothesis.

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